inform masters at Sault Ste. Marie of the weather conditions on the east end of Lake Superior and the north end of Lake Huron.

As previously stated, the lake ships have been equipped far beyond the requirements of law, but the major portion of the commercial fleets of both United States and Canada is still dependent upon the flag and lantern displays. In addition to these unequipped vessels of the larger classes engaged in interlake trade there are numerous small craft, such as fishing vessels and yachts to which the flag and lantern displays are the only available warnings of threatened storm.

I have no hesitancy, therefore, in stating that no thought should be given at the present time to the withdrawal or material contraction of the primitive system of flag and lantern displays. On the contrary, if this service can be expanded to greater usefulness in the saving of life and property the study of the Weather Bureau should be directed to that end. For instance, these signals show merely that a storm may be expected from a certain point of the compass. If a simple revision of the code could be arranged to show the anticipated force of the expected storm, the additional information would be valuable.

I make the further suggestion that the Weather Bureau might render an added service by the forecasting of fluctuations in the lake levels, particularly in the vicinity of the shoal places governing the loading depths of the vessels. Some years ago Mr. Frank Jermin, the meteorologist of the Weather Bureau at Alpena, Mich., made an extensive study of the effects of barometric pressure on the lake levels and the currents created by the transit of the high and low pressure areas from one part of a lake to another. The merits of Mr. Jermin's deductions I am not competent to discuss intelligently with you gentlemen, but I have a distinct recollection that Mr. Jermin said that these water-level fluctuations could be forecast with reasonable accuracy about six hours in advance of their occurrence. If this be true, may I not recommend to my Weather Bureau friends that consideration be given to the issuance of advance information with reference to these fluctuations?

While the poet sings of the "bounding billows" and the "wet sheet and flowing sea," the mariner reads with much greater concern the indications of his barometer and the reports and warning signals of the Weather Bureau. The stories they tell may not be ever new, but the interest holds longer than it does in other Twice-Told Tales.

SIGNIFICANCE OF AIR AND SEA TEMPERATURES OBTAINED ON CRUISE VII OF THE "CARNEGIE"[1]

By KATHARINE B. CLARKE

On the tenth of May, 1928, the nonmagnetic ship, *Carnegie,* sponsored by the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, took departure from Newport News on its seventh cruise. It was possible on this cruise to inaugurate a complete meteorological program. From the middle of May, 1928, to the middle of November, 1929, except for days in port, air pressure, temperature and humidity, and sea temperature were recorded continuously and a definite effort was made to obtain as accurate records as possible. These *Carnegie* observations are particularly valuable because in some regions of the Pacific where the *Carnegie* cruised meteorological data of known accuracy are scanty if not altogether lacking.

Of the meteorological results which are now being compiled at the Department of Terrestrial Magnetism, those of sea and air temperature are the most complete and accurate.

A continuous record of sea-water temperatures at a depth of approximately two meters was obtained with a mercury-in-steel bulb-and-capillary type of sea-water thermograph with daily movement. Sheets were changed daily at Greenwich mean noon. Immediately before each change of sheet the temperature of the surface sea water was measured by the bucket method. This consisted in lowering a canvas bucket into the sea about two feet below the surface, quickly hauling this to the deck and measuring the water temperature by immersing a standardized thermometer in the bucket. The temperature so obtained was entered on the thermogram. In areas where the sea-surface temperature was changing rapidly, as in entering port or in calm weather, a mean of several bucket readings was taken.

The thermograms were scaled at every full hour local mean time. The differences between thermograph and bucket readings have been recorded, and these values, used as a correction factor, applied to the hourly thermograph readings to obtain true sea-surface temperatures. Bucket temperatures were higher than thermograph temperatures by 0°.8 C. to 0°.9 C. at lower sea temperatures and by 0°.2 C. to 0°.1 C. at higher sea temperatures. Comparing temperatures so obtained with the sea-surface temperatures measured at the oceanographic stations with standardized reversing thermometers a difference greater than 0°.5 C. never was found and at over half the stations the difference was less than 0°.1 C. Values of corrected sea-surface temperatures range from 6°.4 C, (43°.5 F.), recorded just south of the Aleutian Islands at 12^h July 8, 1929, to 30°.2 C. (86°.4 F.) approaching Pago Pago at 14^h, November 14, 1929.

For obtaining air temperatures several types of apparatus were used. The Hartmann and Braun electric-resistance multithermograph was installed for the purpose of obtaining lapse rates from deck to masthead. Three pairs of wet and dry bulb thermometers were installed at various heights above sea level—one pair in the Stevenson shelter on deck 12 feet (3.6 meters) above sea level, another pair in a ventilated screen just above the crosstrees on the mainmast 72 feet (21.9 meters) above sea level, and a third pair at the masthead on the mainmast 113 feet (34.6 meters) above sea level. These Thermometers were calibrated from time to time with an Assmann aspiration psychrometer.

The usefulness of these Hartmann and Braun records has been lessened because corrections for all the single thermometers can not be obtained. It is evident that the recorded values depend upon the efficiency of ventilation of the screens, which in turn is modified by direction and velocity of the wind. Unfortunately these wind-records were lost in the destruction of the vessel.

An examination of these Hartmann and Braun records has revealed a diurnal variation in the apparent lapse rates between deck and crosstrees (masthead-records were too incomplete for use). This must be due to heating of the deck-thermometer during the daylight hours.

[1] Based on a paper presented before the American Meteorological Society, Washington, May 4, 1931. Also cf. Brooks, Charles F. Meteorological Program of the Seventh cruise of the *Carnegie,* 1928–1929, MONTHLY WEATHER REVIEW, May, 1929, vol. 57, pp. 194–196.

66718—31——2

It has been possible to use these Hartmann and Braun records in correcting deck-temperatures for overheating, as will be explained later.

The Negretti-Zambra ventilating recording psychrometer was located in the Stevenson screen on the quarterdeck. The recording wet and dry bulb thermometers of this instrument were calibrated daily at Greenwich mean noon by means of an Assmann sling psychrometer. As soon as the wet and dry bulb temperatures were read off on the Assmann they were entered directly on the Negretti-Zambra thermogram. The Negretti-Zambra traces have been scaled at local mean time and hourly values corrected from Assmann reading have been obtained. From these values tables of hourly air temperature, relative humidity, and vapor pressure have been compiled.

Partly as a contribution to climatology and partly to study the diurnal variation of these elements, mean hourly values for areas have been computed. The areas, twenty-two in all, have been selected to represent regions within which small variations of temperature were found, or regions with like variations, such as the Gulf stream crossing. The periods of observation for the areas vary from 3 to 35 days.

As mentioned previously, an examination revealed a diurnal variation in the apparent lapse-rate between deck and crosstree temperatures recorded by the Hartmann and Braun instrument due undoubtedly to overheating of the deck thermometer during the day. Likewise a diurnal variation in differences of temperature recorded by the Hartmann and Braun dry bulb at the crosstrees and the Negretti-Zambra dry bulb in the deck screen has been discovered. The amplitude of this variation, however, is not as great as that of the differences in the two Hartmann and Braun thermometers presumably because the Negretti-Zambra instrument was better ventilated.

It has seemed justifiable to use these curves of differences for computing a correction to be applied to the daytime hourly mean temperatures by areas recorded by the Negretti-Zambra dry bulb. The curve of differences during daylight hours between Negretti-Zambra dry bulb on deck and Hartmann and Braun dry bulb at the crosstrees (means for areas) has been applied as a correction to the mean values of air temperatures. The result of applying these corrections is shown in Figure 6. (Dashed line represents mean air temperature as read from Negretti-Zambra dry bulb and corrected from Assmann readings. Broken line represents what the mean air temperature would be with a correction of the mean differences between Hartmann and Braun deck and crosstree temperatures applied to the Negretti-Zambra dry-bulb means. Full line represents air temperatures corrected for the mean differences of Hartmann and Braun crosstrees and Negretti-Zambra deck dry-bulb temperatures, which is accepted as the most accurate air temperature which can be obtained from the data available.) There are therefore corrected hourly means of sea-surface temperature and of air temperature for 22 areas.

Next a study of the differences between air and sea temperatures was undertaken. Of the daily means for the entire cruise it was found that in 61.5 per cent of the days the mean sea temperature exceeded mean air temperature. On the other 38.5 per cent of the days mean air temperature exceeded mean sea temperature. However, these daily means of air temperature were not corrected for overheating and are undoubtedly too high for actual air temperatures over the sea. Moreover the investigations were all carried out during a summer season or in the tropics and therefore do not represent true annual averages.

In comparing the mean differences for areas between air and sea temperatures, the mean air temperatures corrected for radiation were used. The difference of sea temperature minus air temperature was never as great as 2°0 C. In only two areas, crossing the Gulf stream and in the Gulf of Panama, were mean sea temperatures more than 1°0 C. higher than mean air temperatures. This large difference of 1°6 C. over the Gulf stream may be attributed to the high water temperatures. A difference of 1°5 C. between mean air and sea temperatures in the Gulf of Panama may be explained by the fact that during the entire 12 days of this series the wind was consistently from the southwest—from a region in which sea temperatures only a few hundred miles away were as much as 8° lower than in the gulf. Thus air considerably cooler than gulf water temperature was imported.

It is, also, interesting to note that of the means for the areas which include that part of the cruise from Japan to San Francisco, air temperatures appear to be slightly higher on the average than sea temperatures. Differences are small, from 0°1 C. to 0°7 C. The winds during this part of the cruise usually had a southerly component.

In one other area, that centered off the coast of Chile approximately on the western edge of the Peruvian current, the mean air temperature was 0°11 C. higher than the rather low mean sea temperature here.

From the corrected hourly means for areas a study of diurnal variation has been made. From the literature concerning previous investigations of this subject it was expected that the diurnal variation in differences between air and sea temperatures would be small—about 1° C.—and that in general air temperatures would be lower than sea temperatures during the night and would approach and probably exceed sea temperatures during the day. Mean hourly air temperatures for areas corrected for radiation and for nonperiodic change, and mean hourly sea temperatures for areas corrected for nonperiodic change were used. For the areas which include that part of the cruise from Iceland to the Mid-North Atlantic (17° north, 38° west) and from Barbados to Callao none of the 24 mean hourly air temperatures exceeded the mean hourly sea temperatures. For all other areas the mean hourly air temperature at some time during the day rose higher than the mean sea temperature. However, when air temperatures not corrected for radiation were used in this comparison, for every area except that of the Gulf stream and of the Gulf of Panama air temperatures exceeded sea temperatures sometime during the day. This seems to indicate that if the effect of radiation could be entirely eliminated the mean daily air temperature would seldom exceed mean daily sea temperature.

It was noted that in some of the areas the air temperature exceeded the sea temperature only during the hours between 8 and 10 a. m. In others the air temperature rose above sea temperature about 8 or 9 a. m. and remained above until late afternoon (see fig. 7). A study for the cause of this revealed that in the areas which had an air temperature greater than sea temperature in the morning and then fell below the rest of the day, that the air temperature was at a maximum about 10 a. m. The most plausible explanation for this seemed to be found in the cloudiness records from the log extract and from some atmospheric-electric observations, which indicated that days included in means which had an early maximum were also days when the sky clouded over in the late morning and remained cloudy the rest of the day, thus producing an effect comparable to that of a mountain climate in summer.

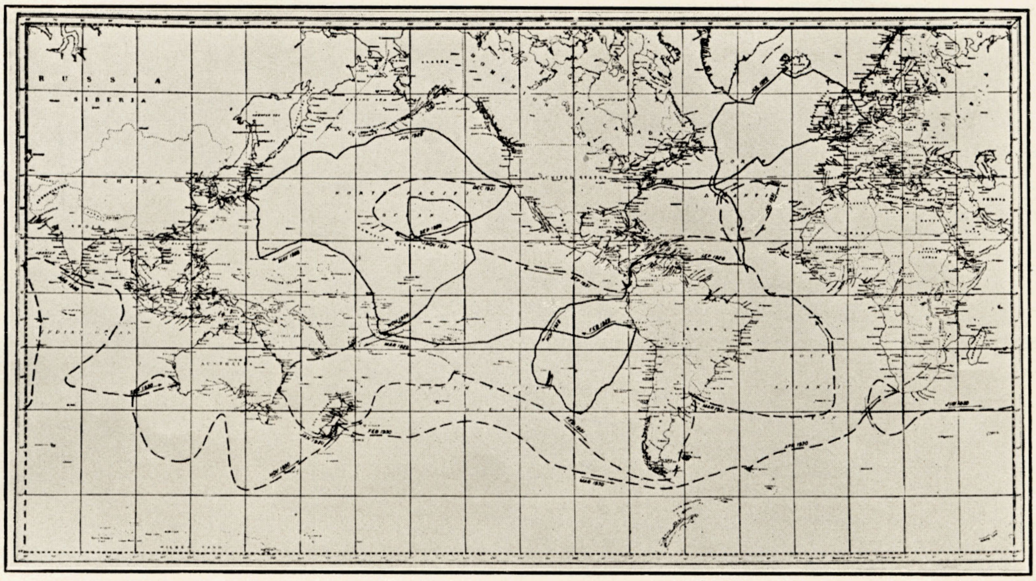

FIGURE 1.—Cruise VII of the *Carnegie*, May ,1928 ,to November ,1929 (broken line shows portion not completed

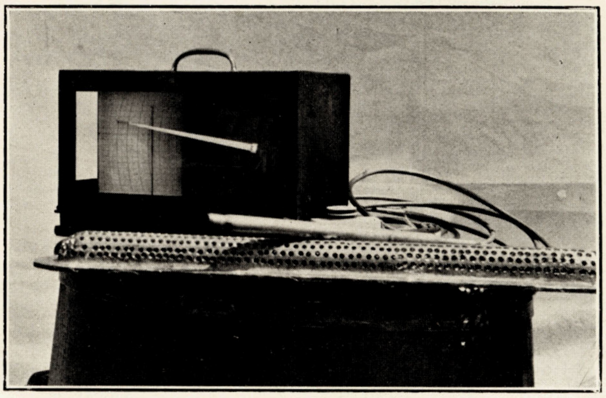

FIGURE 2.—Sea-water thermograph used on *Carnegie*, showing mercury bulb, metal shield, and recording mechanism

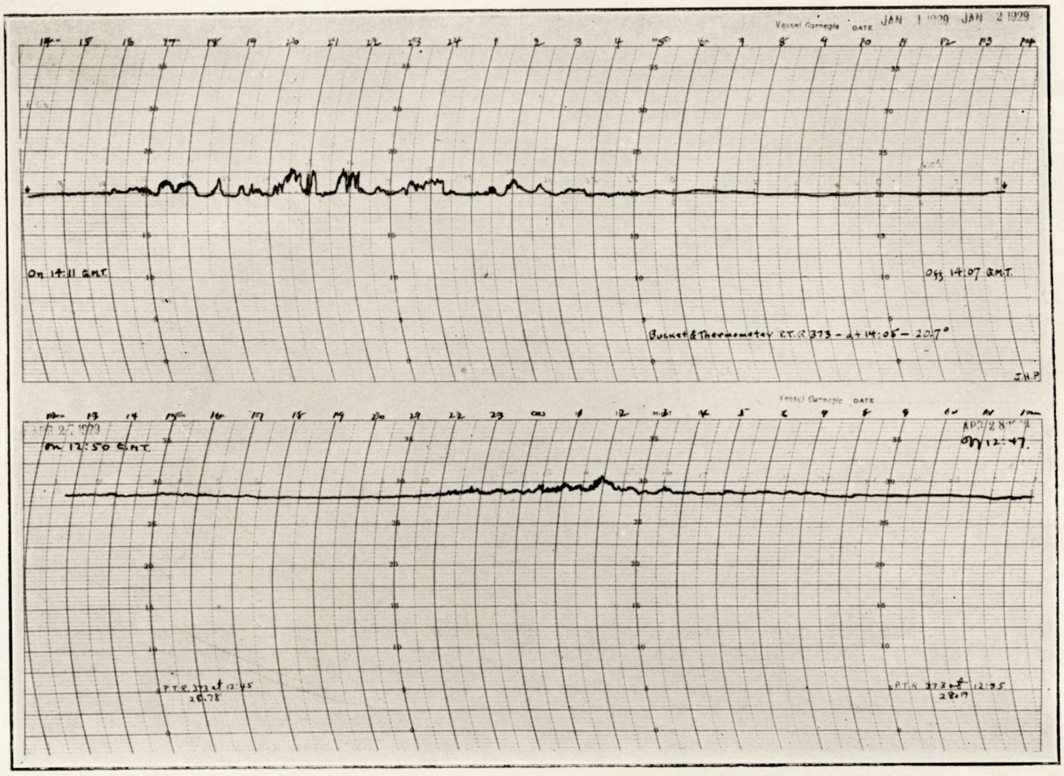

FIGURE 3.—Two thermograms from cruise VII of the *Carnegie* (upper one was obtained on the western edge of the Humboldt Current; lower one is typical of those recorded on calm days in the Tropics)

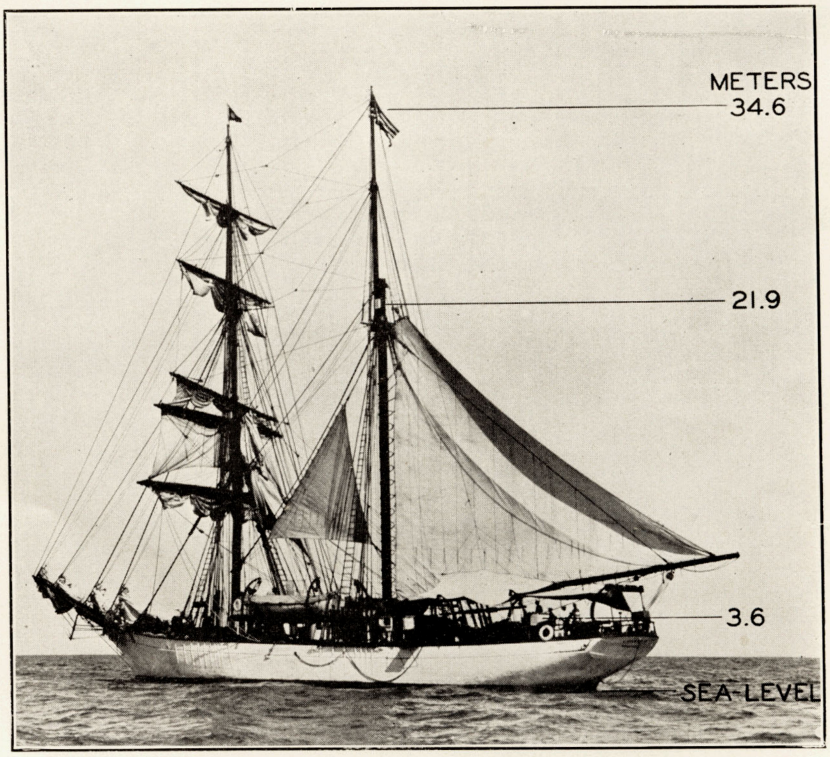

FIGURE 4.—The *Carnegie* showing positions of Hartmann & Braun wet and dry bulb thermometers

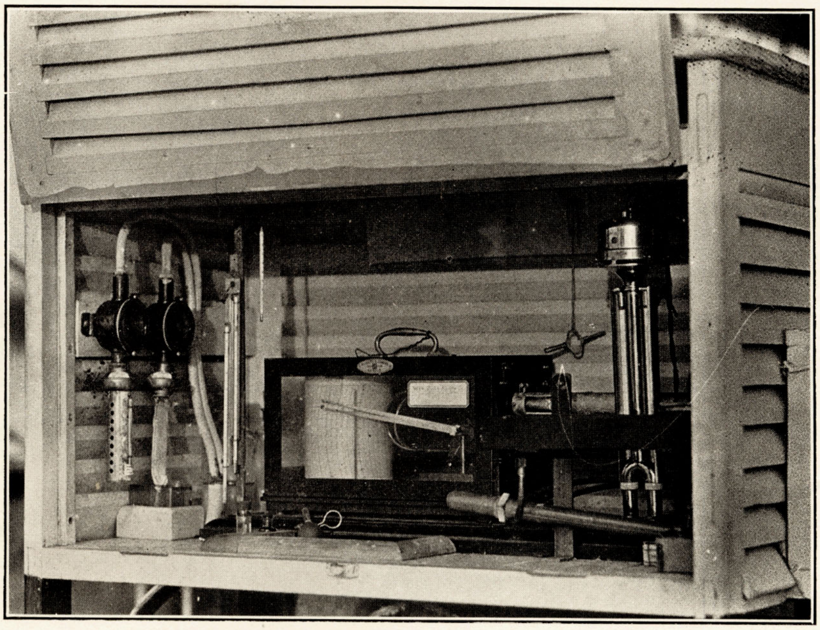

FIGURE 5.—Stevenson screen, open (on left a pair of wet and dry bulb Hartmann & Braun thermometers; in center, Negretti-Zambra ventilating recording psychrometer motor-box outside shelter; Assmann aspiration psychrometer at extreme right)

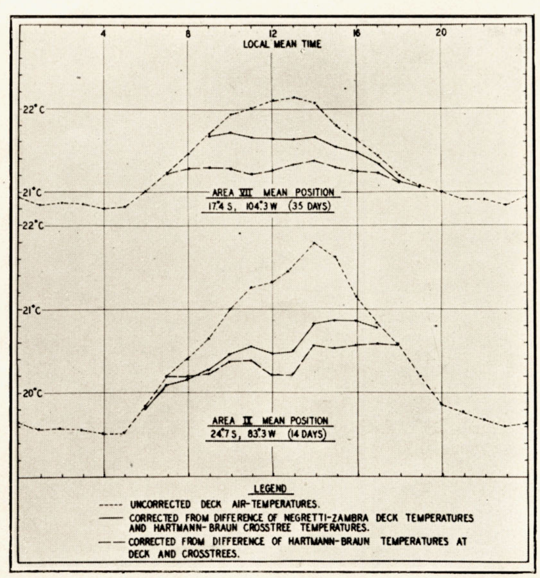

FIGURE 6.—Showing result of correcting excessive daytime temperatures recorded on deck, by means of the diurnal variation in differences between temperatures at deck and crosstree

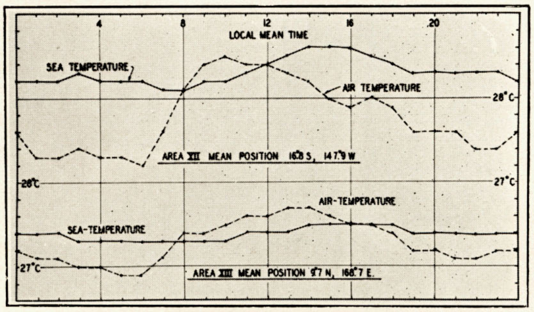

FIGURE 7.—Typical diurnal curves of air and sea temperatures

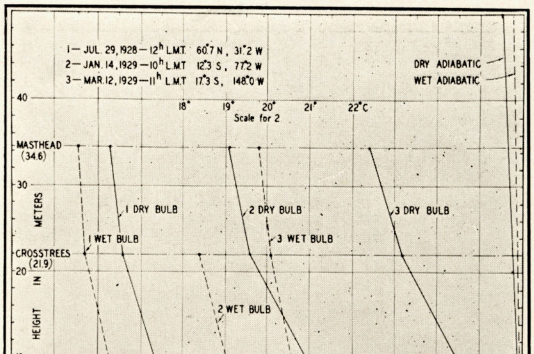

FIGURE 8.—Wet and dry bulb lapse rates

In order to determine to what degree lapse rates obtained by means of thermometers at different heights above deck are useful, the wet and dry bulb temperature at different heights on days when an Assmann calibration with the Hartmann and Braun thermometers was made, were plotted. These daytime lapse rates are shown in Figure 8. The most striking fact is that these rates are decidedly superadiabatic.

(1) July 29, 1928, at 12^h local mean time, off coast of Iceland: The dry bulb at the masthead was 1°5 C. lower than the deck dry bulb, a lapse equal to four times the dry adiabatic. The wet bulb lapse was 1°1 C. between deck and masthead or six times the saturated adiabatic. The weather was cloudy with a moderate NW. breeze, sea moderate with surface temperature of 11°6 C.

(2) January 14, 1929, at 10^h local mean time, entering the port of Callao: There was a dry bulb temperature lapse of 2°1 C. from deck to crosstrees and of 0°5 C. from crosstrees to masthead, a total lapse of 2°6 C. in 35 meters or seven times the dry adiabatic. The wet bulb lapse rate was 1°0 C. between deck and crosstrees or nine times the saturated adiabatic. Wind was SSE., force 3, weather cloudy, sea temperature 18°8 C.

(3) March 12, 1929, at 11^h local mean time, approaching the island of Tahiti: The dry bulb lapse rate was 2°0 C. from deck to crosstrees and 0°8 C. from crosstrees to masthead, a total of 2°8 C. or seven times the dry adiabatic. Wet bulb lapse was 1°1 C. in 35 meters or six times the saturated adiabatic. Weather was squally with gentle NW. breeze. Sea-surface temperature was 28°3 C.

If the deck readings are ignored the lapse rates between crosstees and masthead are respectively two, four, and six times the dry adiabatic. These are exceedingly steep, suggesting that even the crosstree temperatures may have been affected by radiation from deck, sails, and shelter. It is entirely possible that such lapse rates could exist—rates as high as ten or twenty times the dry adiabatic have been observed. Certainly these excessive lapse rates do not represent actual air conditions over the entire ocean for any length of time. It would seem impossible for such unstable conditions to exist throughout a layer of air 35 meters thick for any length of time over any great area.

The results of the study of air and sea temperatures obtained on the *Carnegie* indicate that it is possible to obtain entirely satisfactory sea-surface temperatures with the sea thermograph corrected by careful bucket readings. It seems very probable, however, that air temperatures obtained on a ship at sea, particularly in the summer or in the tropics are too high and do not represent actual conditions over the sea. Since differences between sea and air temperatures are usually less than 1° C., for purposes of studying the physical processes of the atmosphere it becomes necessary to have air temperatures accurate to a tenth of a degree. In order to obtain temperatures of such degree of accuracy methods must be devised for obtaining these continuous temperatures free from the effect of local heating. *Carnegie* data indicate that if air temperatures a few meters above the sea, free from the effects of insolation on the shelter, radiation and heated air could be obtained, it would be found that even the mean hourly air temperatures seldom exceed the sea temperatures. Certainly the sea experts a powerful temperature influence upon the atmosphere.

THE SELECTED-SHIP PROGRAM FOR OCEAN-WEATHER REPORTING BY RADIO

By EDGAR B. CALVERT, Chief, Forecast Division.

[Weather Bureau, Washington]

During the past two years the Weather Bureau has been actively engaged in furthering its share of a project, international in scope, intended to coordinate and improve the work of reporting meteorological conditions at sea by radio. It is not intended that the new scheme, so far as the bureau's own service is concerned, shall supersede the existing arrangement through which it secures by radio, chiefly for its own purpose, a considerable daily collection of reports from ships in the Pacific Ocean and during the hurricane season from ships in the South Atlantic, Gulf of Mexico, and Caribbean Sea. Though the new project is distinctively international in character and is the Weather Bureau's contribution to a world-wide program, it will serve to strengthen materially its own radio weather service from ships at sea.

Weather reports from ships have long been used in advancing knowledge of ocean meteorology and in supplying information concerning storms and other atmospheric conditions over the oceans for the benefit of navigation. In the last quarter of a century ships' weather reports have been collected by radio in increasing numbers, thereby enabling meteorological services to extend daily synoptic charts over the oceans and provide daily forecasts and warnings and synoptic weather information by radiobroadcast for use of ships at sea.

HISTORICAL

A majority of ocean-going vessels traverse waters from which weather reports are needed by the meteorological services of two or more nations. To make weather reports from a ship available to more than one meteorological service, a system of international exchanges must be set up or officers of ships are charged with much additional work in taking observations and forwarding reports to each service separately.

The need of coordination has long been recognized. More than 50 years before the invention of wireless communication, Lieutenant Maury sought more effective cooperation in ocean meteorological work. He attended the First Meteorological Congress in Brussels in 1853, and advocated the establishment of a uniform mode of making nautical and meteorological observations on board vessels of war. The result was that this conference undertook to use a uniform system of meteorological observations both on land and sea all over the world. High honors were bestowed on Maury both in this and other countries because of his work in the fields of oceanography and meteorology, but many may not remember that in 1868, he was appointed professor of meteorology in the Virginia Military Institute at Lexington, which possibly was the first recognition in this way of the science of meteorology by any institution of learning.

Development of wireless communication early in the present century brought many serious complications that did not enter into the program conceived by Maury.

The first wireless message received by the Weather Bureau containing a weather observation from a ship at sea was in December, 1905. Radio weather service from ships at sea was thereafter extended by the Weather Bureau and the weather services of other countries, keep-